User Guide for

FEBFL7730_L20H008B

Dimmable LED Bulb at High Line

Featured Fairchild Product:

FL7730

Direct questions or comments about this evaluation board to: "Worldwide Direct Support"

Fairchild Semiconductor.com

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This FEBFL7730_L20H008B Evalution Board can be identified by the silkscreen marking FL7730 High Line on the top side of the pcb. This user guide supports the evaluation board for the FL7730, FEBFL7730_L20H008B. This kit supersedes the FEBFL7730_L20H008A. The revised kit incorporates the next generation FL7730, which is redesigned for improved dimming performance. It should be used in conjunction with the FL7730 datasheet as well as Fairchild's application notes and technical support team. Please visit Fairchild's website at www.fairchildsemi.com or the evaluation board page http://www.fairchildsemi.com/products/evaluationboards/.

1. Introduction

This document describes the proposed solution for low line voltage LED ballast using the FL7730 Primary Side Regulator (PSR) single-stage controller. The input voltage range is 180 V_{RMS} – 265 V_{RMS} and there is one DC output with a constant current of 380 mA at 22 V_{out}. This document contains general description of FL7730, the power supply specification, schematic, bill of materials, and the typical operating characteristics.

1.1. General Description of FL7730

The FL7730 is an active Power Factor Correction (PFC) controller using single-stage flyback topology. Dimming control with no flicker is implemented by analog sensing method. Primary-side regulation and single-stage topology minimize cost and reduce external components, such as input bulk capacitor and feedback circuitry. To improve power factor and THD, constant on-time control is utilized with internal error amplifier and low bandwidth compensator. Precise constant-current control regulates accurate output current, independent of input voltage and output voltage. Operating frequency is proportionally changed by output voltage to guarantee DCM operation with higher efficiency and simpler designs. FL7730 provides protections such as open-LED, short-LED, and over-temperature protection.

1.2. Features of FL7730

- Compatible with Traditional TRIAC Control
- Cost-Effective Solution without Input Bulk Capacitor and Feedback Circuitry
- Power Factor Correction (PFC)
- Accurate Constant-Current (CC) Control
- Line Voltage Compensation for CC Control
- Linear Frequency Control for Better Efficiency and Simpler Design
- Open-LED Protection
- Short-LED Protection
- Cycle-by-Cycle Current Limiting
- Over-Temperature Protection with Auto Restart
- Low Startup Current: 20μA
- Low Operating Current: 5mA
- Frequency Hopping for EMI
- V_{DD} Under-Voltage Lockout (UVLO)
- Gate Output Maximum Voltage Clamped at 18 V
- SOP-8 Package Available

1.3. Block Diagram

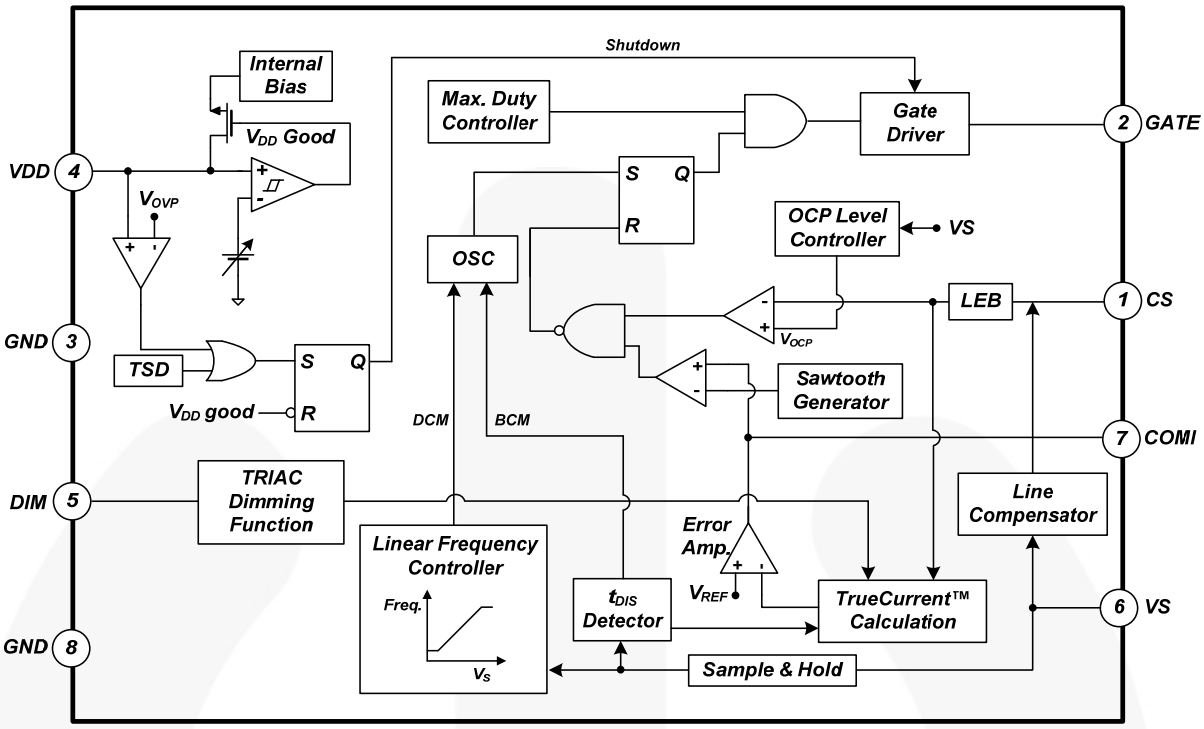


Figure 1. Internal Block Diagram of FL7730

2. General Specifications for Evaluation Board

All data was measured with the board was enclosed in a case and external temperature of approximately 25°C.

Table 1. Evaluation Board Specifications for LED Lighting Bulb

Description	Symbol	Value	Comments
Fairchild Device		FL7730	Control IC of single-stage PSR TRIAC dimming
Input			
Voltage	$V_{IN.MIN}$	180 V	Minimum input voltage
	$V_{IN.MAX}$	265 V	Maximum input voltage
	$V_{IN.NOMINAL}$	220~230 V	Nominal input voltage
Frequency	F_{IN}	50~60 Hz	Line frequency
Output			
Voltage	$V_{OUT.MIN}$	10 V	Minimum output voltage
	$V_{OUT.MAX}$	28 V	Maximum output voltage
	$V_{OUT.NOMINAL}$	22 V	Nominal output voltage
Current	$I_{OUT.NOMINAL}$	380 mA	Nominal output current
	$I_{OUT.RIPPLE}$	±65 mA	Output current ripple
	CC deviation	< ±1.9%	Line input voltage change: 180~265 V_{AC}
		< ±3.1%	Output voltage change: 10~28 V
Efficiency			No dimmer connected
	Eff_{180VAC}	84.5%	Efficiency at 180 V_{AC} line input voltage
	Eff_{220VAC}	84.4%	Efficiency at 220 V_{AC} line input voltage
	Eff_{230VAC}	84.4%	Efficiency at 230 V_{AC} line input voltage
	Eff_{265VAC}	83.8%	Efficiency at 265 V_{AC} line input voltage
PF/THD			No dimmer connected
	PF/THD_{180VAC}	0.97 / 13.7%	PF/THD at 180 V_{AC} line input voltage
	PF/THD_{220VAC}	0.93 / 16.6%	PF/THD at 220 V_{AC} line input voltage
	PF/THD_{230VAC}	0.92 / 17.3%	PF/THD at 230 V_{AC} line input voltage
	PF/THD_{265VAC}	0.87 / 19.7%	PF/THD at 265 V_{AC} line input voltage
Temperature			Open frame condition (Room temp. = 25ºC)
FL7730	T_{FL7730}	46ºC	FL7730 temperature
Primary MOSFET	T_{MOSFET}	53ºC	Primary MOSFET temperature
Secondary Diode	T_{DIODE}	45ºC	Secondary diode temperature
Transformer	$T_{TRNASFORMER}$	48ºC	Transformer temperature
Active Damper	T_{DAMPER}	49ºC	Active damper temperature
Startup Resistor	$T_{STR.RESISTOR}$	55ºC	Startup resistor temperature

3. Photographs

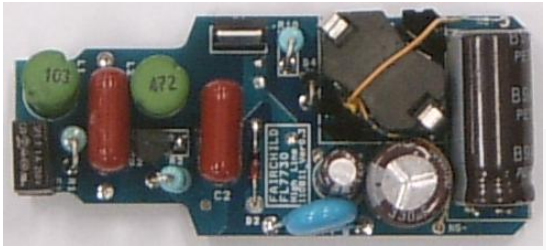


Figure 2. Top View of Board

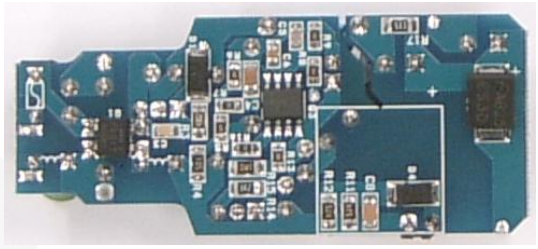


Figure 3. Bottom View of Board

Dimensions: 62.5 mm (L) × 26.8 mm (W) × 12.0 mm (H)

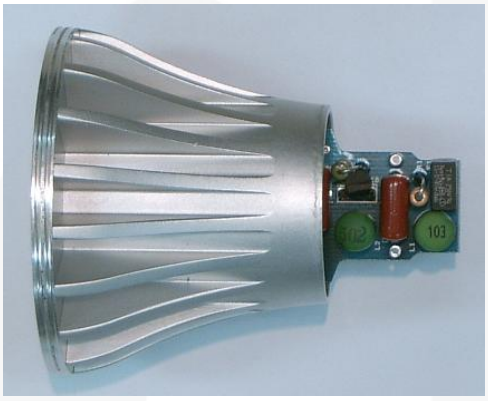


Figure 4. Side View in Bulb Case Type 1

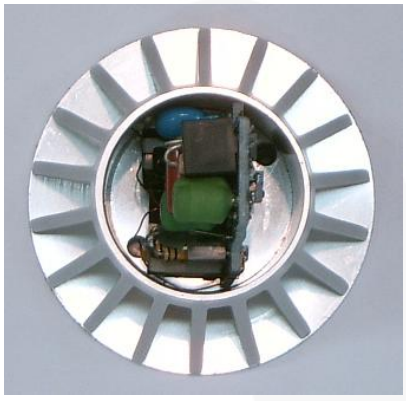


Figure 5. Bottom View in Bulb Case Type 1

Bulb Case Type 1: 32 mm (Case Diameter) × 40 mm (Case Depth)

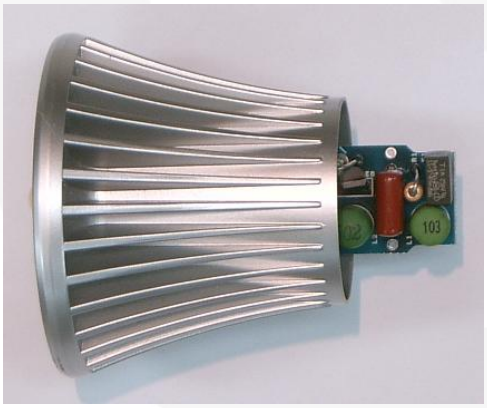


Figure 6. Side View in Bulb Case Type 2

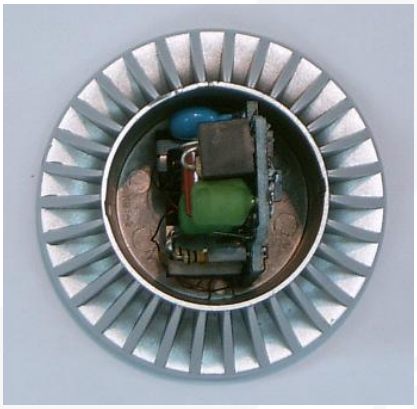


Figure 7. Bottom View in Bulb Case Type 2

Bulb Case Type 2: 34 mm (Case Diameter) × 44 mm (Case Depth)

4. Printed Circuit Board

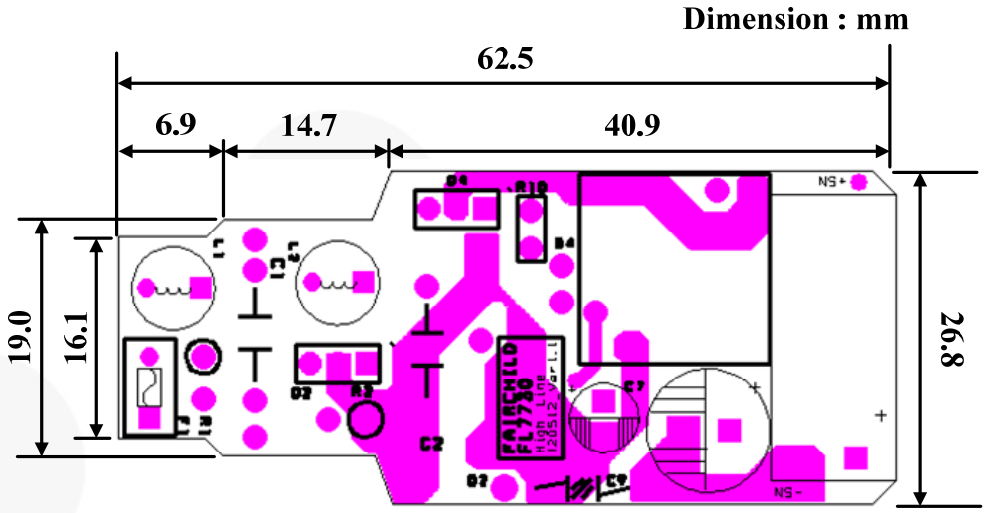


Figure 8. Top Pattern of Board

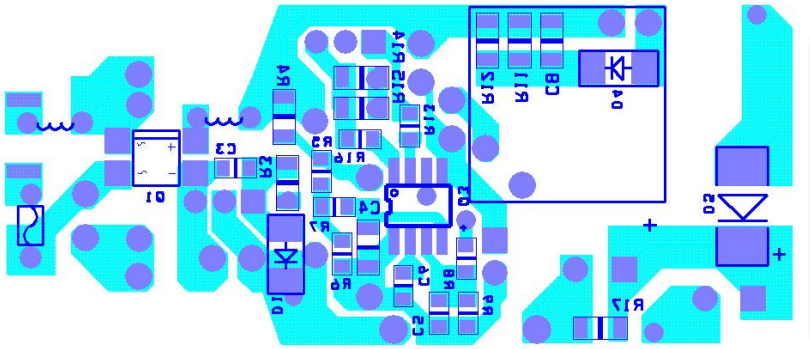


Figure 9. Bottom Pattern of Board

5. Schematic of the Evaluation Board

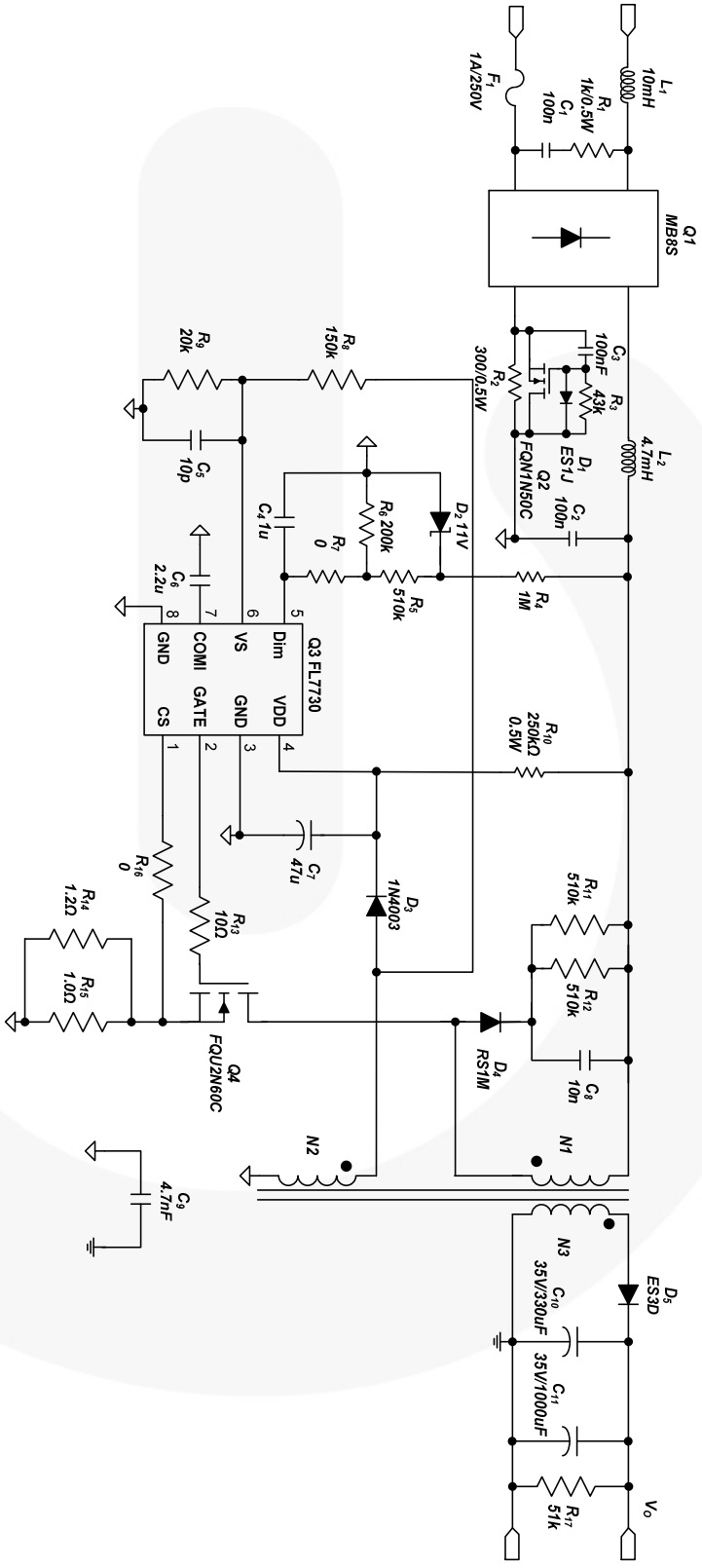


Figure 10. FL7730 Schematic

6. Bill of Materials

Item No.	Part Reference	Part Number	Qty.	Description	Manufacturer
1	Q1	MB8S	1	Bridge Diode	Fairchild Semiconductor
2	Q2	FQN1N50C	1	1 A / 500 V Active Damper MOSFET	Fairchild Semiconductor
3	Q3	FL7730MY_F116	1	Main Controller	Fairchild Semiconductor
4	Q4	FQU2N60C	1	2 A / 600 V Main Switch	Fairchild Semiconductor
5	F1	SS-5-1A	1	1 A / 250 V Fuse	Bussmann
6	L1	R06103KT00	2	10 mH Filter Inductor	Bosung
7	L2	R06472KT00	2	4.7 mH Filter Inductor	Bosung
8	D1	ES1J	1	1 A / 600 V Diode	Fairchild Semiconductor
9	D2	1N5241	1	11 V Zener Diode	Fairchild Semiconductor
10	D3	1N4003	1	1 A / 200 V Diode	Fairchild Semiconductor
11	D4	RS1M	1	1 A / 1000 V Diode	Fairchild Semiconductor
12	D5	ES3D	1	3 A / 200 V Fast Rectifier	Fairchild Semiconductor
13	C1, C2	MPE 400V104K 14S	1	100 nF / 400 V Film Capacitor	Sungho
14	C3	C0805C104K3RACTU	1	100 nF / 25 V SMD Capacitor 2012	Kemet
15	C4	C1206C105K3PACTU	1	1 µF / 25 V SMD Capacitor 3216	Kemet
16	C5	C0805C100M3GACTU	1	10 pF / 25 V SMD Capacitor 2012	Kemet
17	C6	C2012Y5V1E225Z	1	2.2 µF / 25 V SMD Capacitor 2012	TDK
18	C7	KMG 47 µF / 35 V	1	47 µF / 35 V Electrolytic Capacitor	Samyoung
19	C8	C1206C103KDRACTU	1	10 nF / 1 kV SMD Capacitor 3216	Kemet
20	C9	SCFz2E472M10BW	1	4.7 nF / 250 V Y-Capacitor	Samwha
21	C10	KMG 330 µF / 35 V	1	330 µF / 35 V Electrolytic Capacitor	Samyoung
22	C11	RM 1000 µF / 35 V	1	1000 µF / 35 V Electrolytic Capacitor	Samwha
23	R1	SFR2500001001FR500	1	1k Ω / 0.5 W Metal Resistor	Vishay
24	R2	RNF12JTD300R	1	300 Ω / 0.5 W Metal Resistor	Stackpole Electrical
25	R3	RC1206JR-0743KL	1	43 kΩ SMD Resistor 3216	Yageo
26	R4	RC1206JR-071ML	1	1 MΩ SMD Resistor 3216	Yageo
27	R5	RC0805JR-07510KL	1	510 kΩ SMD Resistor 2012	Yageo
28	R6	RC0805JR-07200KL	1	200 kΩ SMD Resistor 2012	Yageo
29	R7	RC0805JR-070R0L	1	0 Ω SMD Resistor 2012	Yageo
30	R8	RC0805JR-07150KL	1	150 kΩ SMD Resistor 2012	Yageo
31	R9	RC0805JR-0720KL	1	20 kΩ SMD Resistor 2012	Yageo
32	R10	RNF12GTD250K	1	250 kΩ / 0.5W Metal Resistor	Stackpole Electrical
33	R11, R12	RC1206JR-07510KL	2	510 kΩ SMD Resistor 3216	Yageo
34	R13	RC0805JR-0710RL	1	10 Ω SMD Resistor 2012	Yageo

Bill of Materials (Continued)

Item No.	Part Reference	Part Number	Qty.	Description	Manufacturer
35	R14	RC1206JR-071R2L	1	1.2 Ω SMD Resistor 3216	Yageo
36	R15	RC1206FR-071RL	1	1.0 Ω SMD Resistor 3216	Yageo
37	R16	RC0805JR-070RL	1	0 Ω SMD Resistor 2012	Yageo
38	R17	RC1206JR-0751KL	1	51 kΩ SMD Resistor 3216	Yageo

7. Transformer Design

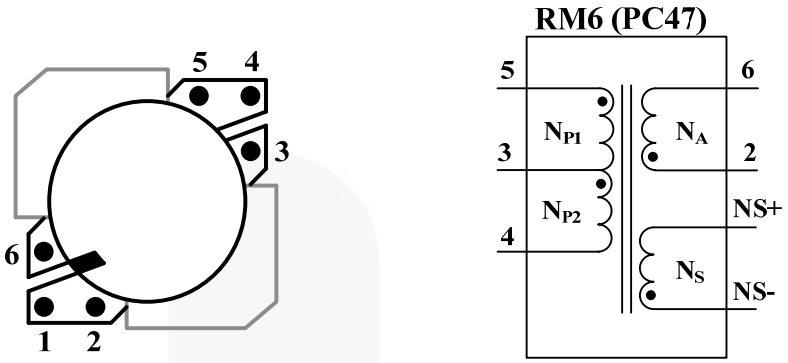


Figure 11. Transformer Bobbin Structure and Pin Configuration

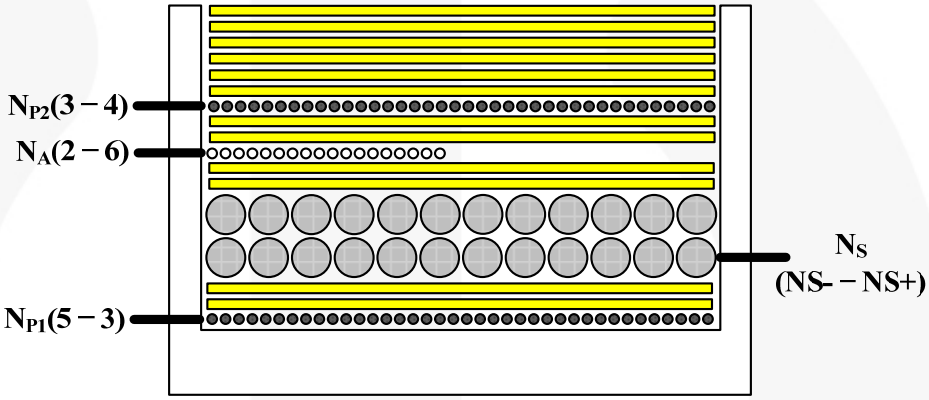


Figure 12. Transformer Winding Structure

Table 2. Winding Specifications

No	Winding	Pin (S → F)	Wire	Turns	Winding Method
1	N_{P1}	5 → 3	0.13φ	38 Ts	Solenoid Winding
2	Insulation: Polyester Tape t = 0.025 mm, 2 Layers				
3	N_S	NS- → NS+	0.3φ (TIW)	24 Ts	Solenoid Winding
4	Insulation: Polyester Tape t = 0.025 mm, 2 Layers				
5	N_A	2 → 6	0.13φ	18 Ts	Solenoid Winding
6	Insulation: Polyester Tape t = 0.025 mm, 2 Layers				
7	N_{P2}	3 → 4	0.13φ	38 Ts	Solenoid Winding
8	Insulation: Polyester Tape t = 0.025 mm, 6 Layers				

Table 3. Electrical Characteristics

	Pin	Specification	Remark
Inductance	1– 2	1 mH ±10%	50 kHz, 1 V
Leakage	1– 2	8 μH	50 kHz, 1 V Short all output pins

8. Performance of Evaluation Board

8.1. Startup

Startup time is 0.7 s. There is no overshoot at output current and voltage in startup sequence. (Refer I_{OUT} and V_{DD} waveform: V_{DD} indicates a reflected output voltage.)

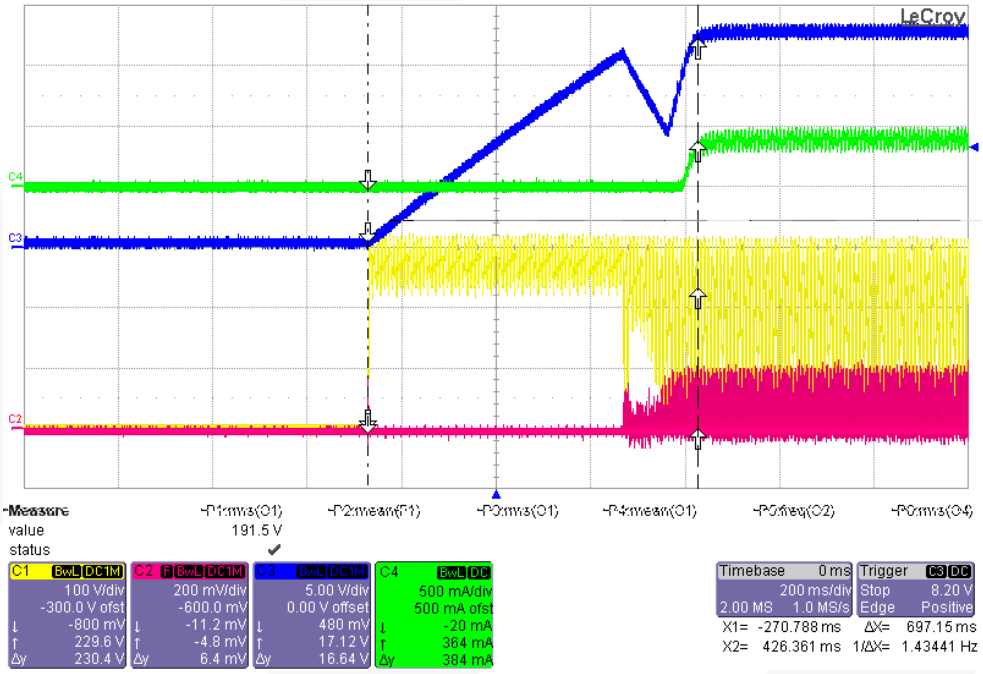
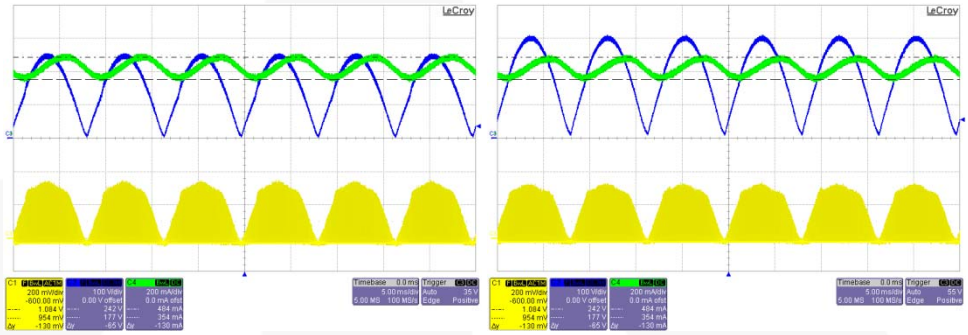


Figure 13. Startup – V_{IN}[220V_{AC}] C1[V_{IN}] C2[V_{CS}] C3[V_{DD}] C4[I_{OUT}] (No Dimmer Connected)

8.2. Operation Waveforms

In steady state, line compensation regulates output current regardless of input voltage variations. Output current ripple is ±65 mA with a rated output current of 380 mA.

V_{IN} = 180 V_{AC} V_{IN} = 220 V_{AC}



V_{IN} = 230 V_{AC} V_{IN} = 265 V_{AC}

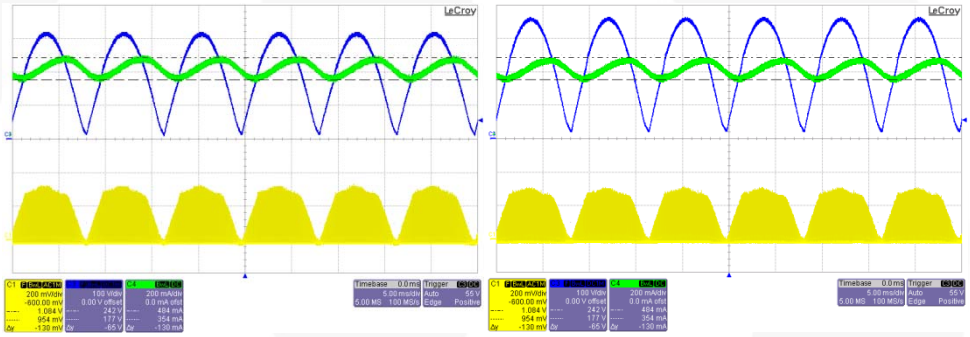


Figure 14. Operation Waveforms – V_O[22V] I_O[380mA] C1[V_{CS}] C3[V_{IN}] C4[I_{OUT}]

8.3. Constant Current Regulation

Constant current deviation in the wide output voltage range from 10 V to 28 V is less than 3.1% at each line input voltage. Line regulation at the rated output voltage (22 V) is less than 1.7%

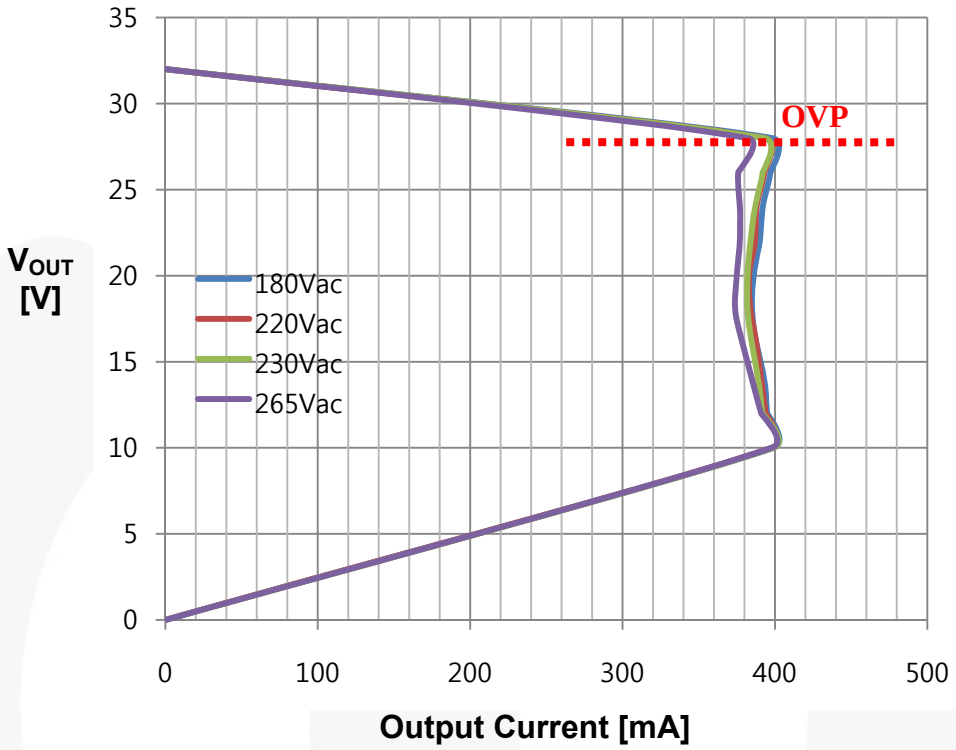


Figure 15. Constant Current Regulation – Measured by E-Load [CR Mode]

Table 4. Constant Current Regulation by Output Voltage Change (10~28 V)

Input Voltage	Min. Current	Max. Current	Tolerance
180 V_{AC} / 60 Hz	385 mA	399 mA	±1.8%
220 V_{AC} / 60 Hz	383 mA	398 mA	±1.9%
230 V_{AC} / 60 Hz	382 mA	399 mA	±2.2%
265 V_{AC} / 60 Hz	374 mA	398 mA	±3.1%

Table 5. Constant Current Regulation by Line Voltage Change (180~265 V_{AC})

Output Voltage	180 V_{AC}	220 V_{AC}	230 V_{AC}	265 V_{AC}	Tolerance
20 V	392 mA	388 mA	387 mA	377 mA	±1.9%
22 V	390 mA	387 mA	384 mA	377 mA	±1.7%
24 V	386 mA	383 mA	382 mA	375 mA	±1.4%

8.4. Open-LED and Short-LED Protections

In short-LED condition, the OCP level is reduced from 0.7 V to 0.2 V because the FL7730 lowers the OCP level when the V_S voltage is less than 0.4 V during output diode conduction time. The output current in the short-LED condition is less than 1.5 A, which doesn't damage external components.

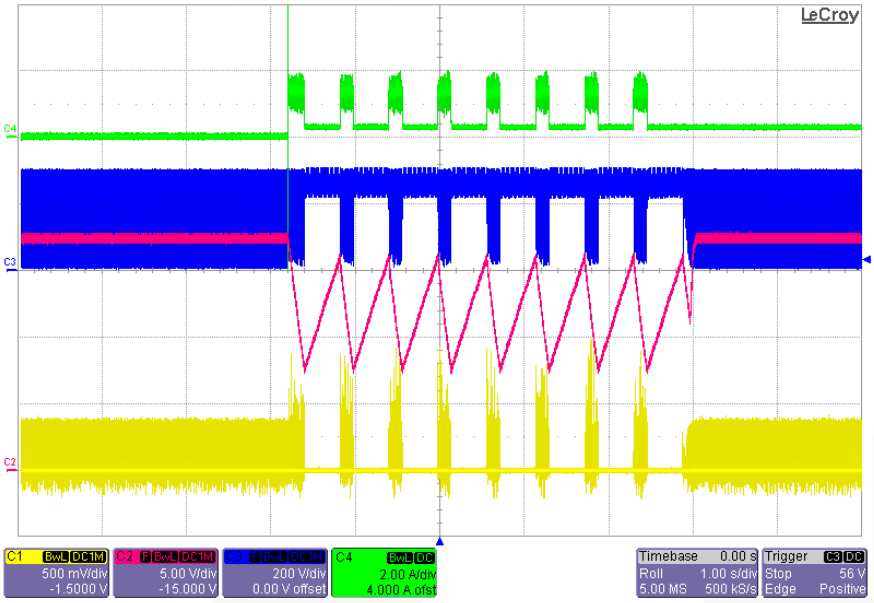

LeCroy
C4
C3
C2
C1 500 mV/div -1.5000 V
C2 5.00 V/div -15.000 V
C3 200 V/div 0.00 V offset
C4 2.00 A/div 4.000 A ofst
Timebase 0.00 s Roll 1.00 s/div 5.00 MS 500 kS/s
Trigger Stop 56 V Edge Positive

Figure 16. Short-LED Condition – V_{IN}[220 V_{AC}] C1[V_{CS}] C2[V_{DD}] C3[V_{IN}] C4[I_{OUT}]

In open-LED condition, output voltage is limited around 32 V by OVP in V_{DD}. The output over-voltage protection level can be controlled by the turn ratio of the auxiliary and secondary windings.

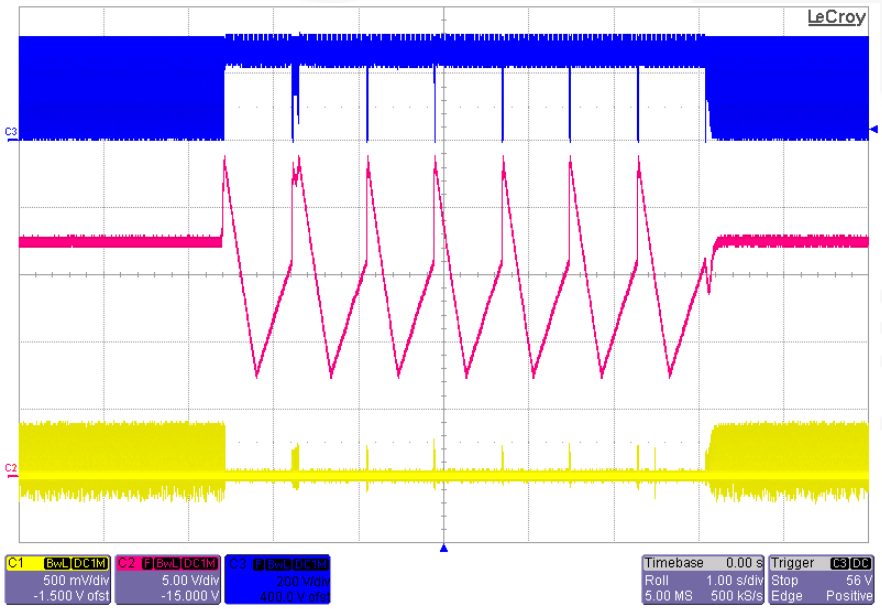

LeCroy
C3
C2
C1 500 mV/div -1.500 V ofst
C2 5.00 V/div -15.000 V
C3 200 V/div 400.0 V ofst
Timebase 0.00 s Roll 1.00 s/div 5.00 MS 500 kS/s
Trigger Stop 56 V Edge Positive

Figure 17. Open-LED Condition – V_{IN}[220 V_{AC}] C1[V_{CS}] C2[V_{DD}] C3[V_{IN}]

8.5. Dimming Operation

Dimming operation waveforms are shown in Figure 18 through Figure 21. Active damper, RC bleeder, and dimming control in FL7730 implement flicker-free dimming oepration. Spike current at dimmer firing is less than 1 A.

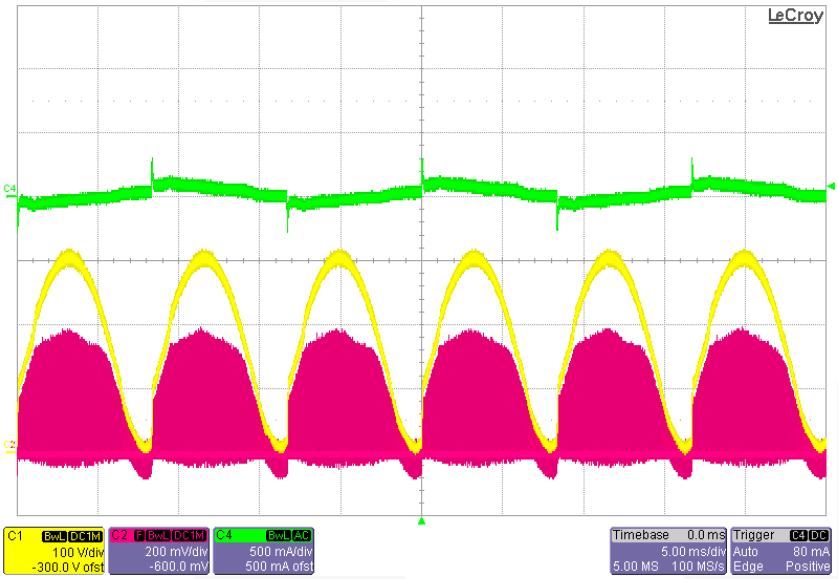


Figure 18. Dimming Operation Waveforms – Max. Dimming Angle, V_{IN}[220 V_{AC}] C1[V_{IN}] C2[V_{CS}] C4[I_{IN}]

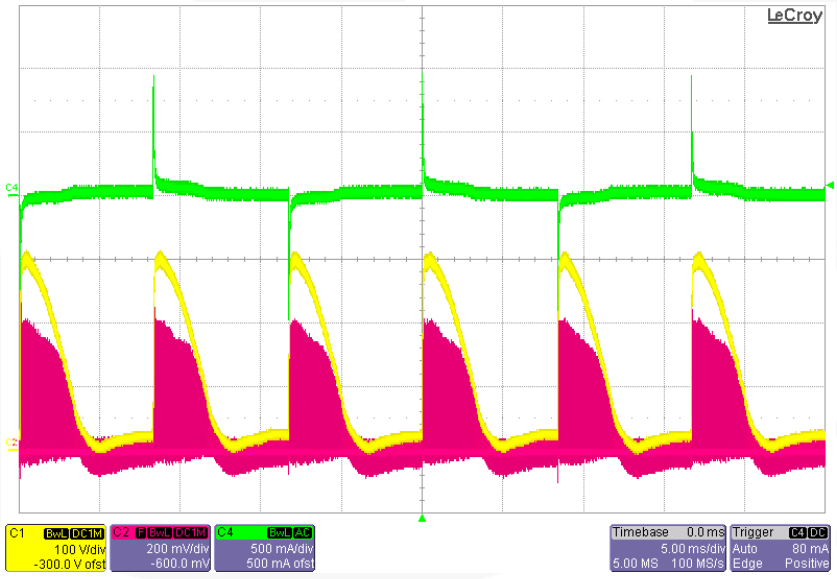


Figure 19. Dimming Operation Waveforms – 90º Dimming Angle, V_{IN}[220 V_{AC}] C1[V_{IN}] C2[V_{CS}] C4[I_{IN}]

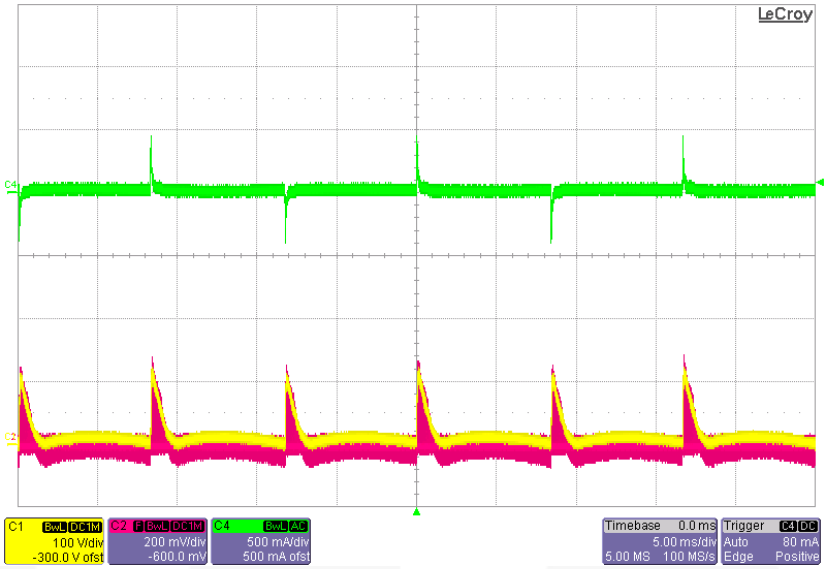

LeCroy
C4
C2
C1 BwL DC1M 100 V/div -300.0 V ofst
C2 BwL DC1M 200 mV/div -600.0 mV
C4 BwL AC 500 mA/div 500 mA ofst
Timebase 0.0 ms 5.00 ms/div 5.00 MS 100 MS/s
Trigger C4 DC Auto 80 mA Edge Positive

Figure 20. Dimming Operation Waveforms – Min. Dimming Angle, V_{IN}[220 V_{AC}] C1[V_{IN}] C2[V_{CS}] C4[I_{IN}]

Output current is controlled by the dimming function when rotating dimmer switch as below dimming curve. The dimming control block in the FL7730 smoothly changes regulated output current by detecting dimming angle.

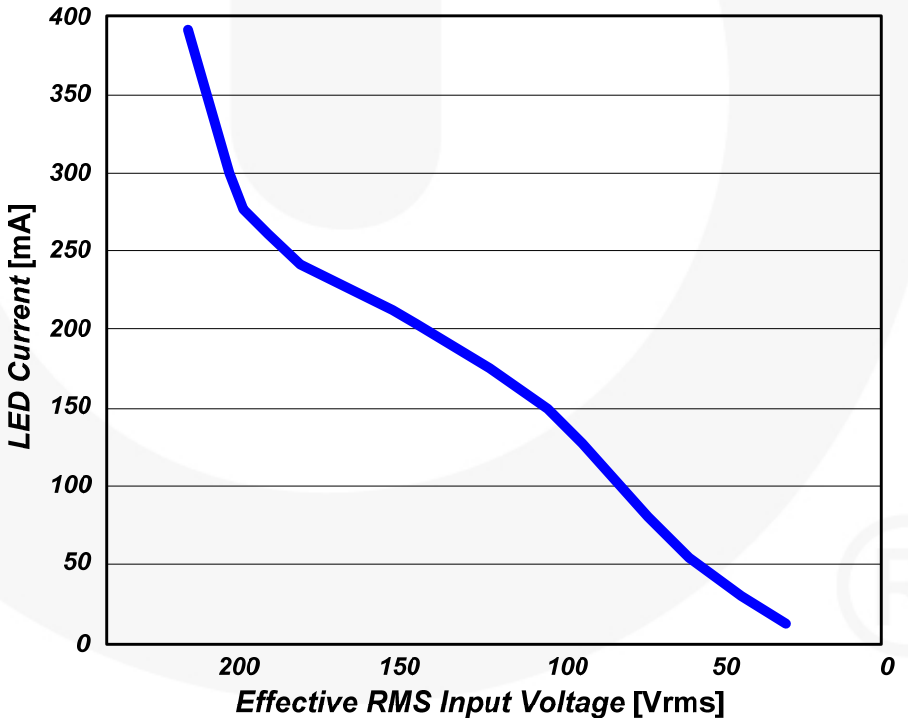


Figure 21. Dimming Curve (Effective RMS Input Voltage vs. Output Current) – Line Voltage[220 V_{AC}]

Table 6. Dimmer Compatibility

Manufacturer	Dimmer	Condition	Max Current	Min Current	Flicker
NANO	SKD-500	220 V / 60Hz	365 mA	24 mA (7%)	No
JIN HEUNG	SA04003	220 V / 60Hz	364 mA	53 mA (15%)	No
ANAM	D-500	220 V / 60Hz	350 mA	58 mA (17%)	No
OPPLE	P068102	220 V / 60Hz	378 mA	6 mA (2%)	No
DAESUNG	SKD-500	220 V / 60Hz	366 mA	6 mA (2%)	No
GIRA	226200	230 V / 50Hz	319 mA	64 mA (20%)	No
GIRA	30000	230 V / 50Hz	335 mA	80 mA (24%)	No
JUNG	225NVDE	230 V / 50Hz	320 mA	70 mA (22%)	No
JUNG	ST550	230 V / 50Hz	325 mA	100 mA (31%)	No
JUNG	266GDE	230 V / 50Hz	332 mA	61 mA (18%)	No
KOPP	8033	230 V / 50Hz	300 mA	100 mA (33%)	No
BUSCH	2200	230 V / 50Hz	338 mA	66 mA (20%)	No
BUSCH	2247U	230 V / 50Hz	323 mA	108 mA (33%)	No
BUSCH	2250	230 V / 50Hz	335 mA	60 mA (18%)	No
MERTEN	5721	230 V / 50Hz	365 mA	30 mA (8%)	No
PEHA	436	230 V / 50Hz	306 mA	120 mA (40%)	No
EVERFLORISH	EF700DC [Trailing]	230 V / 50Hz	327 mA	154 mA (47%)	No
MERTEN	577129 [Trailing]	230 V / 50Hz	330 mA	147 mA (44%)	No
BUSCH	6513 [Trailing]	230 V / 50Hz	353 mA	145 mA (41%)	No

The FL7730 high-line board shows good dimmer compatibility without flicker.

To reduce the minimum LED current, follow the below design guide:

- Reduce DIM resistors (R5 and R6) to decrease minimum DIM voltage. (DIM offset voltage by DIM internal current source (7.5 μA) is reduced by smaller R6.)
- Increase the bleeder capacitor (C1). (When reducing minimum LED current, bleeder current should be larger to stabilize input current without flicker. However, increasing C1 reducees PF. This is always trade-off of “flicker-free design vs. PF” in RC bleeder structure.)

8.6. System Efficiency

Power efficiency is 83.8 ~ 84.5% in 180 ~ 265 V_{AC} input voltage range.

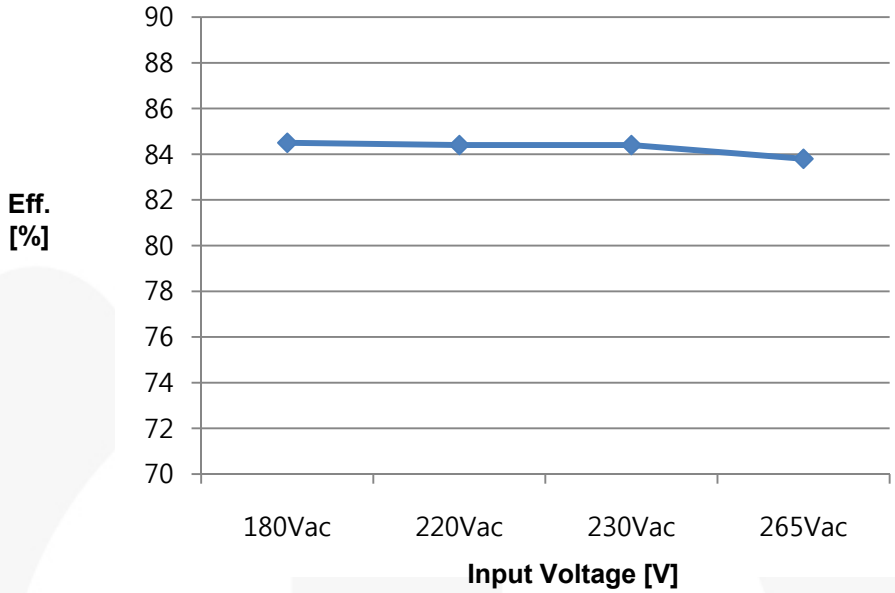


Figure 22. Power Efficiency (Input voltage vs. Efficiency)

Table 7. System Efficiency

Input Voltage	Input Power	Output Current	Output Voltage	Output Power	Efficiency
180 V_{AC}	10.13 W	392 mA	21.84 V	8.56 W	84.5%
220 V_{AC}	9.97 W	386 mA	21.80 V	8.41 W	84.4%
230 V_{AC}	9.94 W	385 mA	21.79 V	8.39 W	84.4%
265 V_{AC}	9.76 W	376 mA	21.75 V	8.18 W	83.8%

8.7. Power Factor and Total Harmonic Distortion (THD)

The FL7730 shows excellent power factor and THD performance. Power factor is over 0.9 at 180~230 V_{AC}. THD is less than 30% of the specification.

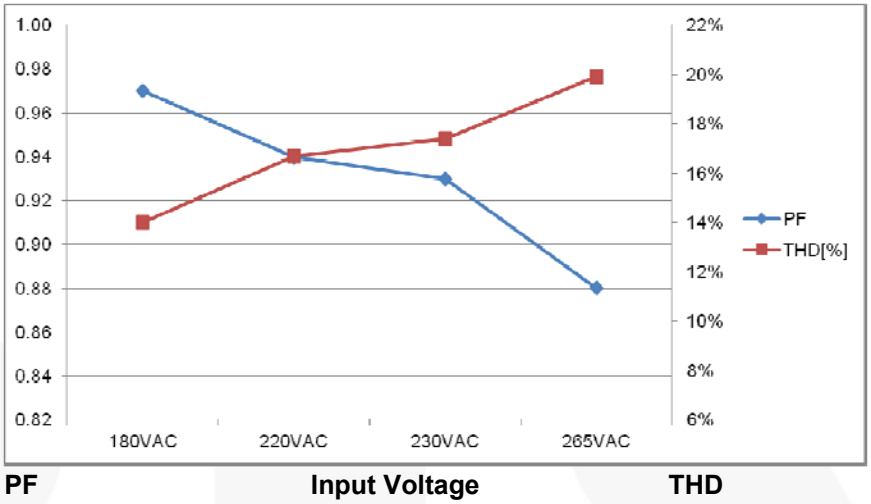


Figure 23. PF & THD (50 Hz)

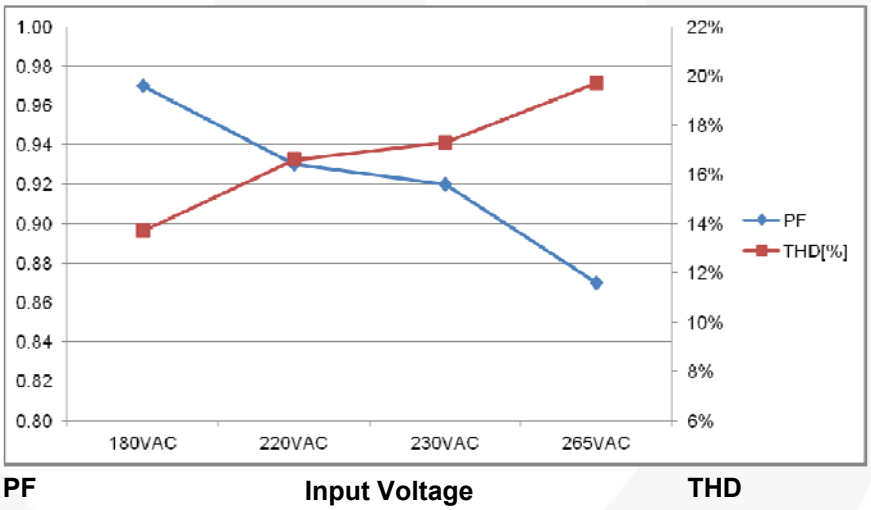


Figure 24. PF & THD (60 Hz)

Table 8. Power Factor and THD

Input Voltage	Output Current	Output Voltage	Frequency	PF	THD
180 V_{AC}	392 mA	21.84 V	50 Hz	0.97	14.0%
			60 Hz	0.97	13.7%
220 V_{AC}	386 mA	21.80 V	50 Hz	0.94	16.7%
			60 Hz	0.93	16.6%
230 V_{AC}	385 mA	21.79 V	50 Hz	0.93	17.4%
			60 Hz	0.92	17.3%
265 V_{AC}	376 mA	21.75 V	50 Hz	0.88	19.9%
			60 Hz	0.87	19.7%

8.8. Operating Temperature

Temperature of the all components on this board is less than 55ºC.

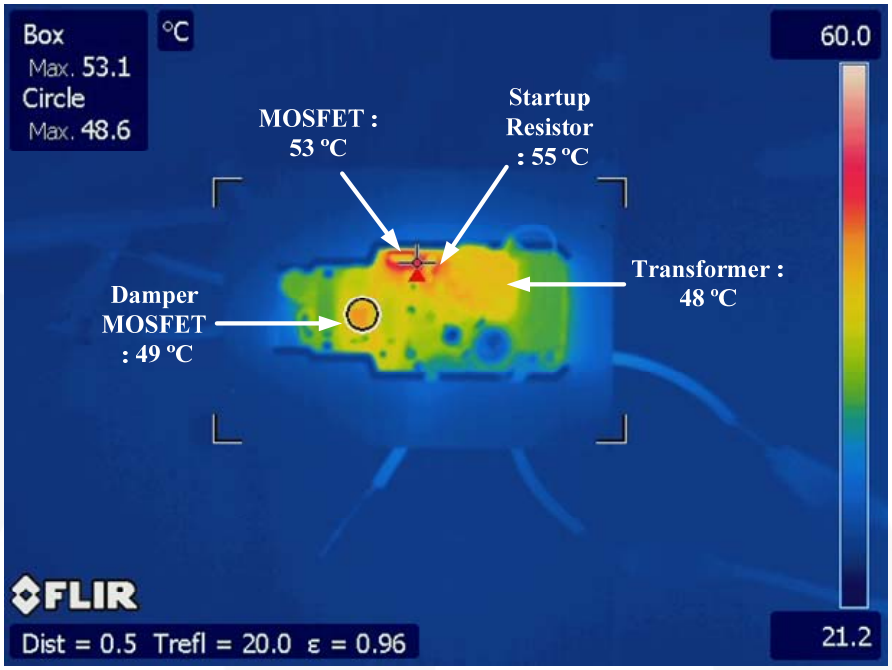


Figure 25. Board Temperature - Top View, V_{IN}[220 V_{AC}] I_O[380 mA]

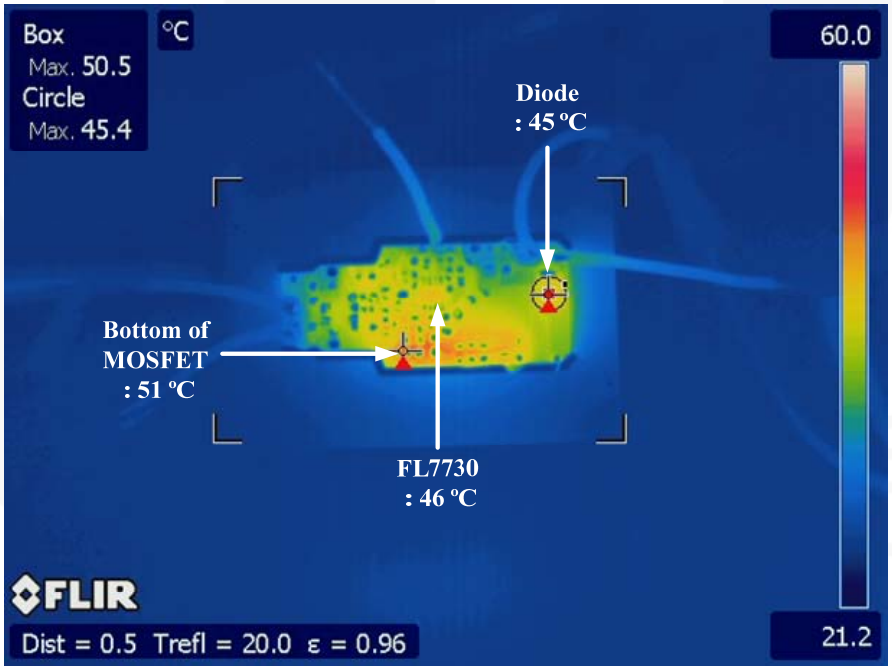


Figure 26. Board Temperature - Bottom View, V_{IN}[220 V_{AC}] I_O[380 mA]

8.9. EMI

The all measurement was conducted in observance of CISPR22 criteria.

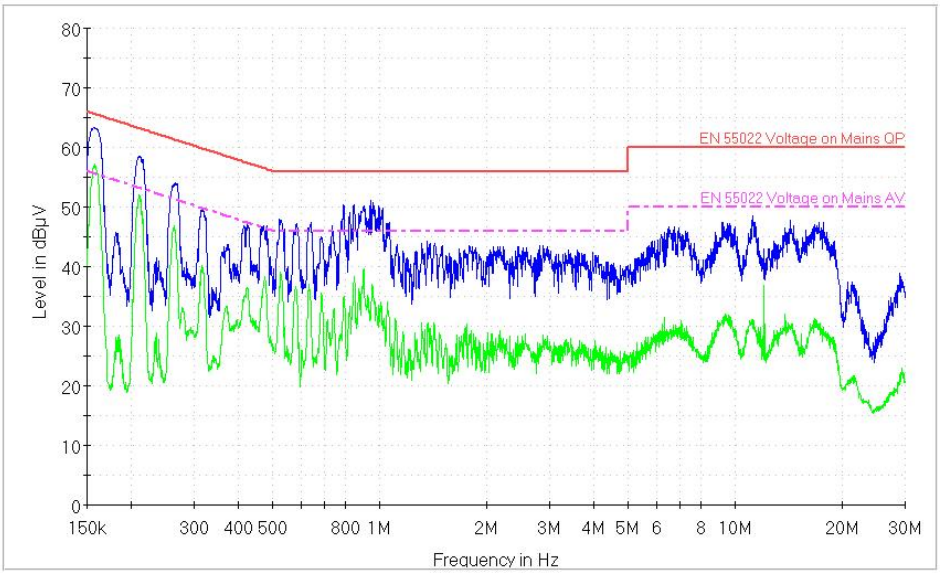


Figure 27. EMI Results – V_{IN}[220 V_{AC}] V_{OUT}[22 V], I_{OUT}[380 mA]

9. Revision History

Rev.	Date	Description
1.0.0.	Oct. 2011.	Initial Release
1.1.0	Aug. 2012.	Manufacturer & Part number are added in BOM FL7730 is changed to FL7730MY_F116 (no frequency hopping) Dimmer compatibility table is updated PF/THD at 50Hz is added EMI test result is updated Updating to match new naming conventions

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